

# Combustion



## Combustion Annual Report Fiscal Year 2003

### **Industrial Technologies Program**

Boosting the productivity and competitiveness of U.S. industry  
through improvements in energy and environmental performance



**U.S. Department of Energy**  
**Energy Efficiency and Renewable Energy**

# Industrial Technologies Program – Boosting the Productivity and Competitiveness of U.S. Industry

Industry consumes 33 percent of all energy used in the United States. By developing and adopting more energy-efficient technologies, U.S. industry can boost its productivity and competitiveness while strengthening national energy security, improving the environment, and reducing emissions linked to global climate change.

The U.S. Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy (EERE) works in partnership with U.S. industry to increase the efficiency of energy and materials use, both now and in the future. Through an innovative strategy known as Industries of the Future (IOF), EERE's Industrial Technologies Program (ITP) seeks to improve the energy intensity of the U.S. industrial sector through a coordinated program of research and development (R&D), validation, and dissemination of energy efficiency technologies and operating practices. ITP develops, manages, and implements a balanced portfolio that addresses industry requirements throughout the technology development cycle. The primary long-term strategy is to invest in high-risk, high-return R&D. Investments are focused on technologies and practices that provide clear public benefit but for which market barriers prevent adequate private-sector investment.

The IOF strategy maximizes the energy and environmental benefits of ITP's process-specific technology investments by forming collaborative partnerships with energy-intensive industries. These collaborations aim to effectively plan and implement comprehensive R&D agendas and help disseminate and share best energy management practices throughout the United States. The IOF public-private partnerships also facilitate voluntary efforts, such as the President's Climate VISION initiative, to encourage industry and government to reduce greenhouse gas emissions. ITP focuses its resources on a small number of energy-intensive materials and process industries that account for over 75 percent of industrial energy consumption:

- Aluminum
- Chemicals
- Forest Products
- Glass
- Metal Casting
- Mining
- Petroleum Refining
- Steel

ITP also conducts R&D projects on enabling technologies that are common to many industrial processes such as industrial energy systems, combustion, materials, and sensors and process control systems. In addition, ITP funds technical assistance activities to stimulate near-term adoption of best energy-saving technologies and practices within industry. These activities include plant assessments, tool development and training, information dissemination, and showcase demonstrations.

New technologies that use energy efficiently also lower emissions and improve productivity. By leveraging technical and financial resources of industry and government, the IOF partnerships have generated significant energy and environmental improvements that benefit the nation and America's businesses. Energy-intensive industries face enormous competitive pressures that make it difficult to make the necessary R&D investments in technology to ensure future efficiency gains. Without a sustained commitment by the private and public sectors to invest in new technology R&D and deployment, the ability to close the gap between U.S. energy supply and demand will be severely compromised.

# CONTENTS

**Executive Summary** ..... iv

**Combustion Systems Overview** ..... 1

Energy Use ..... 1

**The Challenge** ..... 3

Improved Emissions Control ..... 3

Strategy for Improving Combustion Systems Energy Efficiency ..... 3

**FY 2003 Highlights & Accomplishments** ..... 5

R&D Highlights ..... 6

**Tools, Publications, and Resources Available** ..... 7

Combustion Resources ..... 7

Process Heating Resources ..... 7

Steam System Resources ..... 8

Combined Heat and Power Resources ..... 9

Energy Analysis - Targeting Energy Efficiency ..... 9

**How To Get Involved and Contact Information** ..... 11

Partnership Information ..... 11

Access to Resources and Expertise ..... 11

Where to Go for More Information ..... 12

# EXHIBITS

1. Industries of the Future Combustion Systems End Users .....	1
2. U.S. Manufacturing Energy End Uses .....	1
3. Steam Energy Use by Industry .....	2
4. Fired Heaters Energy Use by Industry .....	2
5. Combustion Portfolio Goals Summary .....	4
6. Active Combustion Projects in FY 2003 .....	5
7. Other Projects Relevant to the Combustion Portfolio .....	5

# EXECUTIVE SUMMARY-INDUSTRIAL COMBUSTION SYSTEMS

Combustion systems have been a crucial tool for industrial development throughout the world. The manufacturing sector continues to rely on these systems for heat and steam generation. Combustion systems include turbines, process heaters, boilers, and combined heat and power (CHP) technologies. The systems enable indispensable industrial processes, such as heating metals and chemical feedstocks, as well as the ability to change the mechanical and chemical properties of materials. Major end users include energy-intensive industrial sectors, such as petroleum, metals, and forest products.

Fueled by environmental concerns such as global warming and ozone transport, emission requirements have had a major influence on the design and implementation of combustion systems. In addition, combustion energy represents almost 75 percent of the total U.S. manufacturing sector energy use. With such high energy consumption levels and emission constraints, there is a constant need for system optimization. This increases R&D needs for fundamental combustion science, as well as better heat-transfer understanding and improved system designs.

## A Successful Partnership with Industry

The U.S. Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy (EERE) leads the federal role in developing advanced energy-efficient and environmentally friendly industrial technologies. Industrial combustion systems R&D is an element of the overall EERE strategy and supports the goals of the National Energy Policy. Improvements in industrial combustion systems can reduce energy consumption through more efficient heat transfer to the load; reduce NO<sub>x</sub>, SO<sub>2</sub>, CO, and particulate emissions; and improve product quality.

There are a large number of opportunities for companies to develop and apply new combustion technologies. However, these opportunities generally involve a high capital risk in the event that the technology might not achieve sufficient market acceptability. Additionally, the lack of technology transfer capabilities can slow down the responses aimed at addressing U.S. industry's needs. To facilitate this knowledge transfer base, the Combustion portfolio provides cost-shared funding for crosscutting R&D projects of interest to a range of industries. Through the Industries of the Future process, ITP provides cost-shared funding for combustion-related projects identified as priorities by specific industries. The Combustion portfolio successfully accelerates technology transfer activities and helps the nation save energy and reduce our dependence on fossil fuels.

## Achieving Energy Savings: Portfolio Strategy

The Combustion initiative aims to tackle the barriers that impede improvement of industrial combustion systems, while addressing the R&D needs of burner, boiler, and furnace systems. To satisfy long-term goals without ignoring valuable short-term opportunities that can improve energy efficiency, the strategy supports development of state-of-the-art technologies, as well as the improvement of current technologies.

The FY 2003 Combustion portfolio includes three combustion projects. In addition, other combustion-related projects are funded by Industries of the Future or other ITP initiatives. More information about the Combustion portfolio is available on the ITP Web site at: [http://www.oit.doe.gov/combustion/rd\\_portfolio.shtml](http://www.oit.doe.gov/combustion/rd_portfolio.shtml).

## FY 2003 Highlights

**Forced Internal Recirculation Burner** – By combining several techniques, the Forced Internal Recirculation (FIR) family of burners significantly reduces NO<sub>x</sub> and CO emissions without sacrificing efficiency or performance. These burners were originally developed for package boilers firing natural gas, and are now commercially available. They are being expanded for use in multi-burner, field-erected boilers in the steel industry that fire byproduct gases with natural gas and/or oil backup. Target NO<sub>x</sub> emissions for this project is <15 vppm (volumetric parts per million) NO<sub>x</sub>, representing a more than 90 percent reduction from current

uncontrolled levels. Development and demonstration partners include Peabody Engineering Corporation and a U.S. coke oven boiler site. Co-funding is provided by Gas Technology Institute and GTI's Sustaining Membership Program.

**Ultra-Low NO<sub>x</sub> Burners with Flue Gas Recirculation and Partial Reformer** – The goal of this project is to develop low excess-air, ultra-low NO<sub>x</sub> natural gas-fired industrial burners that can emit less than 5 vppm NO<sub>x</sub>. Work is currently underway for the development of the first commercial low-swirl burner. Project partners include Lawrence Berkeley National Laboratory, Coen Co., CMC Engineering, John Zink Co., Gasunie Research, Maxon Corporation, and MIT Plasma Science and Fusion Center.

**Process Heat Combustion System** – The goal of this project is to develop designs and components for a low-cost, integrated process heater technology, with optimum system performance in terms of efficiency, emissions, flexibility, reliability, and safety. This project integrates three advanced technologies: 1) ultra-low emission burners; 2) a specially designed, fired heater with advanced heat recovery; and 3) an online, process-tube, temperature-sensing and burner control system to enhance heat transfer, reduce maintenance costs, and increase run lengths. The system has an energy-savings potential of 84 trillion Btu/year, as well as the potential to reduce NO<sub>x</sub> emissions by 10,000 tons and decrease capital costs by \$1.5 billion by 2020. Partners for this project include TIAX LLC, ExxonMobil, and Callidus Technologies.

**Super Boiler** – This project aims to create ultra-low emission, ultra-high efficiency steam-generation technologies that will be integrated in a package boiler. The Gas Technology Institute has teamed up with Cleaver-Brooks, a major U.S. boiler manufacturer, to design, build, and test laboratory and commercial prototype versions of a first-generation, gas-fired Super Boiler. The performance goals include 94 percent fuel efficiency, 5 vppm NO<sub>x</sub> and CO, and 50 percent size and weight reduction compared to a conventional firetube boiler. Potential natural gas savings are estimated at 503 trillion Btu per year in 2020, or more than \$2 billion at current fuel prices. In addition to DOE's support, the Super Boiler project is supported by GTI Sustaining Membership Program, Southern California Gas Company, Cleaver Brooks Division of Aqua-Chem, and the Gas Technology Institute.

## **R&D Highlights**

### **Steel**

Oscillating combustion has the potential to increase heat transfer and reduce NO<sub>x</sub> emissions by up to 75 percent in many high-temperature, natural gas-fired furnaces. This is done by creating fuel-rich and fuel-lean zones. At a ladle preheater in a steel mini-mill, this retrofit technology has already demonstrated significant NO<sub>x</sub> reductions and a 5 percent efficiency improvement. The technology is currently being demonstrated on a batch annealing furnace in a steel mill.

Dilute-oxygen combustion systems have been proven to require less fuel to heat steel, and give lower flue gas temperatures, as shown in a commercial demonstration at a steel rolling mill site. This novel technology allows reheat furnaces to operate economically at higher production rates without increasing NO<sub>x</sub> emissions.

### **Aluminum**

After a series of field demonstrations, a new, oxygen-enhanced combustion melting system has shown a 30 percent increase in productivity and 40 percent energy savings, while achieving reduced carbon and NO<sub>x</sub> emissions.

### **Glass**

A commercial demonstration is underway for a new, high-temperature burner that increases radiant heat transfer and luminosity. This could result in improved thermal efficiency and energy efficiency, and reduced NO<sub>x</sub> emissions.

Productivity increases of 5 percent to 10 percent, paralleled with reductions in NO<sub>x</sub> emissions of up to 50 percent in an oxy-fuel fired, fiberglass, melting furnace, were obtained from oscillating combustion technologies.

Oxygen-enriched air staging technology can offer the potential for 50 percent to 70 percent NO<sub>x</sub> reductions while maintaining quality and productivity. This technology is now available commercially and in use at several container glass plants.

#### **Petroleum**

A novel rotary burner design that operates with a natural draft and uses the energy embodied in gas-supply pressure is currently in the demonstration phase. This technology achieves a 5 percent energy use reduction while attaining ultra-low NO<sub>x</sub> emissions (below 1 vppm).

#### **Forest Products**

In commercial power plants, methane de-NO<sub>x</sub><sup>TM</sup> reburn retrofits have proven their adaptability to burn high-volume biomass, wood wastes, and sludge, resulting in boiler energy efficiency improvements and reduced wastes and air emissions.

# COMBUSTION SYSTEMS OVERVIEW

Industrial combustion systems are essential to the U.S. manufacturing sector and, consequently, to the U.S. economy. The total value of shipments for the top seven U.S. combustion-based industries is estimated at \$890 billion. Every state with industry relies on combustion for everyday performance, and virtually every industry requires some form of combustion for operation. Exhibit 1 lists the end users of industrial combustion systems by system type.

Combustion-based industries also represent an enormous source of employment. The top seven U.S. combustion-based industries employ more than 3 million people.

## Energy Use

Combustion systems are used to generate steam and heat for manufacturing processes. Combustion systems account for almost 75 percent of total energy end use in the U.S. manufacturing sector. Specifically, fired heaters represent 38 percent of total energy end use, and steam systems account for 35 percent, as shown in Exhibit 2.

Steam systems consume 6,201 trillion Btu annually. The most steam-intensive industries are forest products (1,381 TBtu), chemicals (1,055 TBtu), and petroleum refining (680 TBtu). Exhibit 3 shows the amount of steam energy used by each industry.

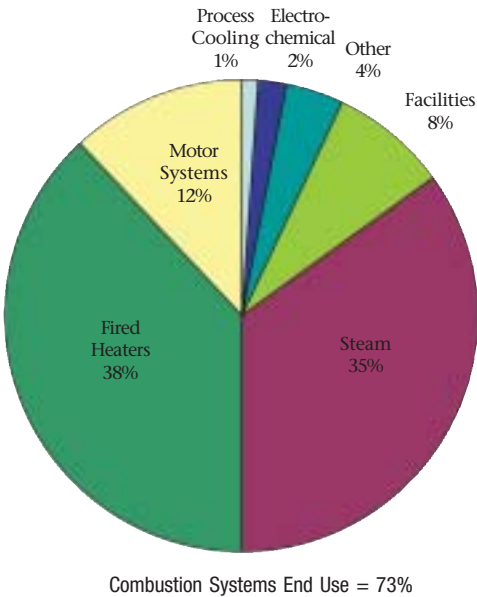
Of the overall energy inputs for steam systems, 45 percent is lost in boilers, distribution, and energy conversion. Boilers account for the largest losses in steam systems, totaling 1,233 trillion Btu. Boiler efficiency ranges from 55 percent to almost 90 percent, and the average boiler efficiency is estimated at less than 80 percent. Almost 1 quad is lost in steam distribution, which represents 15 percent of the overall steam system losses. Energy conversion losses, such as losses from heat exchangers, preheat systems, and other equipment, total 597 trillion Btu. The remaining 3,380 trillion Btu are used in the various manufacturing processes.

Fired heaters consume 6,672 trillion Btu/year. The petroleum refining industry is the largest energy consumer, with 2,067 trillion Btu. Iron and steel mills, and the chemical industry are also very large consumers, with 1,326 and 1,099 trillion Btu, respectively. Exhibit 4 shows a distribution of the total energy used for fired heaters by each individual industry.

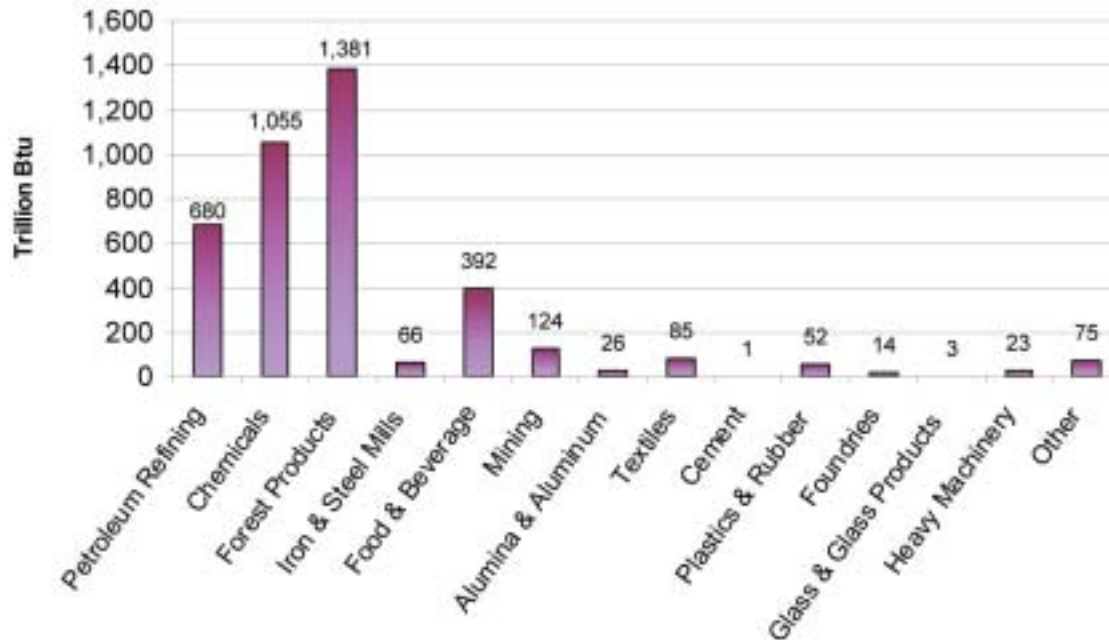
Exhibit 1 Industries of the Future  
Combustion Systems End Users

Industry	Combustion Systems		
	Burners	Boilers	Furnaces
Aluminum	●		●
Chemicals	●	●	●
Forest Products	●	●	
Glass	●	●	●
Metal Casting	●		●
Mining	●	●	●
Petroleum	●	●	●
Steel	●	●	●

Exhibit 2 U.S. Manufacturing Energy End Uses

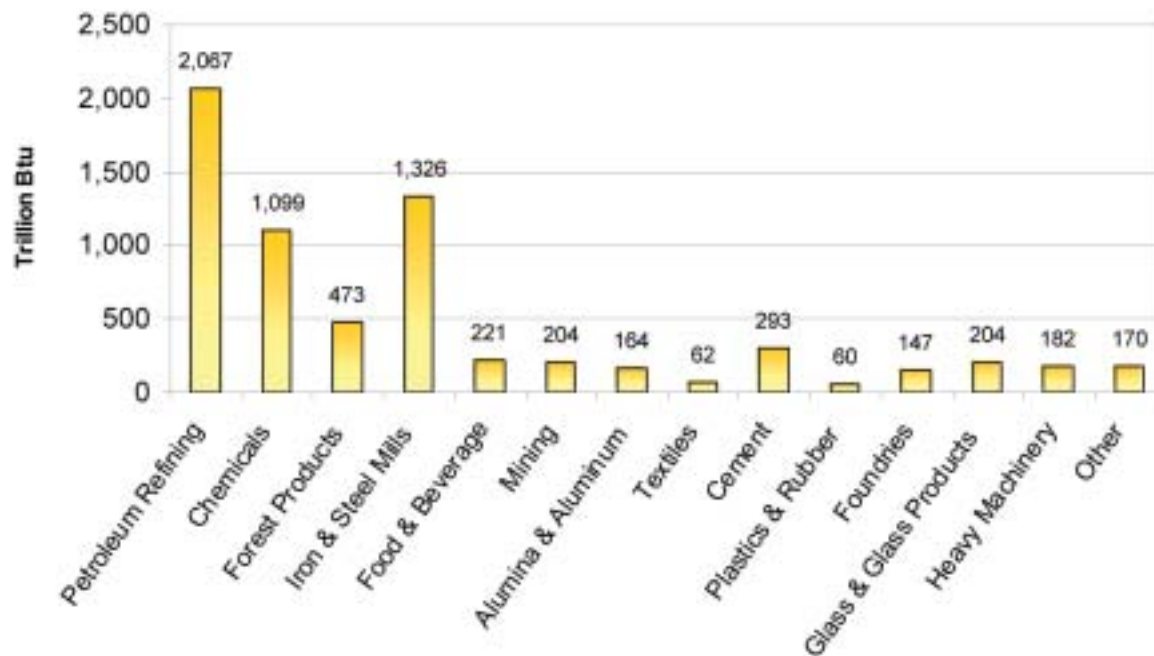


**Exhibit 3 Steam Energy Use by Industry**



Source: MECS 1998

**Exhibit 4 Fired Heaters Energy Use by Industry**



# THE CHALLENGE

The challenges of improving combustion processes are highly complex. In recent years, combustion systems research has focused on emissions reduction and energy efficiency. The challenge has been to develop clean systems without compromising their efficiency. The combustion equipment industry is a highly fragmented, low-margin sector that has inadequate resources to tackle these R&D challenges alone. Through collaborative R&D partnerships, DOE and industry are creating the foundation for enhanced combustion performance, focusing on applications outlined as priorities by the IOFs, and identified in the combustion vision and technology roadmap.

Developments at the component level remain important. From a total systems perspective, the optimization of combustion processes depends on breakthroughs in efficiency, productivity, safety, and environmental performance. To accomplish these breakthroughs, it is imperative to attain higher levels of sophistication in computational science and systems engineering. Combustion is one of the most complex chemical processes known, and effective computational modeling and simulation of combustion comprise a great part of the challenge.

The historical approach to combustion systems design and tuning is trial and error. The aid of advanced modeling and improved systems engineering capabilities can bring more predictability to combustion design, resulting in the creation of systems that can deliver heat to the load with unprecedented precision, reliability, and efficiency.

## Improved Emissions Control

The goal of achieving low-cost solutions to criteria-pollutant emission control without sacrificing energy efficiency remains a priority for the Combustion portfolio. In the combustion vision and roadmap, equipment end users anticipate requirements for nitrogen oxides ( $\text{NO}_x$ ) emissions of under 10 ppm in the near-term, and 2 ppm over the coming decades. Presently, the scientific advances that allow for the achievement of single-digit emissions have been achieved. However, further advances in technology are required to attain acceptable cost, performance, and reliability levels.

## Strategy for Improving Combustion Systems Energy Efficiency

The Combustion portfolio within the U.S. Department of Energy's Industrial Technology Program (ITP) provides crosscutting support for technology development relevant to the nine Industries of the Future (IOFs). The Combustion portfolio is steered by two documents: 1) the *Combustion Industry Vision* (developed from an ITP-sponsored workshop in 1998) describes the long-range view of industry stakeholders, and 2) the *Industrial Combustion Technology Roadmap* (developed in 1999 and updated in 2001) establishes specific targets that will need to be met to achieve the vision. Exhibit 5 summarizes the Combustion portfolio goals.

At present, Combustion portfolio funding is fully engaged in support of three projects. However, these projects address only a portion of the opportunities for energy savings that exist within the Industries of the Future. As part of the strategy, it is important that the projects remain on schedule and deliver the promised energy savings. Combustion portfolio managers work closely with the other teams sponsoring combustion-related projects to maximize the impact of those projects. Simultaneously, opportunities are identified where teams might collaborate in the development of new combustion technologies that are relevant to their portfolio goals.

***The overall goals of the Combustion portfolio support the ITP goal of reducing specific energy consumption in the nine IOFs by 30 percent by 2020 (compared to 2002 baseline).***

## Exhibit 5 Combustion Portfolio Goals Summary

Boilers	<ul style="list-style-type: none"> <li>• Maximize system efficiency by achieving 150 F stack exit temperature</li> <li>• Improve system reliability by 50 percent</li> <li>• Maximize integration of steam and power production</li> <li>• Reduce first cost and life-cycle costs</li> <li>• Improve safety</li> </ul>
Boiler Burners	<ul style="list-style-type: none"> <li>• Achieve NO<sub>x</sub> emissions below 2 vppm</li> <li>• Reduce CO emissions below 5 vppm</li> <li>• Reduce particulate emissions below 0.003 lb/MMBtu</li> <li>• Maximize multi-fuel capability</li> </ul>
Furnaces	<ul style="list-style-type: none"> <li>• Reduce the total cost of combustion in manufacturing</li> <li>• Reduce product loss ratio by 50 percent</li> <li>• Enhance system integration</li> <li>• Maximize system robustness</li> <li>• Zero accidents</li> </ul>
Furnace Burners	<ul style="list-style-type: none"> <li>• Achieve 90 percent reduction of criteria pollutants vs. 1990 baseline</li> <li>• Reduce CO<sub>2</sub> emissions per international agreements</li> <li>• Reduce specific fuel consumption by 20-50 percent</li> <li>• Maximize multi-fuel capability</li> </ul>

# FY 2003 HIGHLIGHTS AND ACCOMPLISHMENTS

The Combustion portfolio supports cost-shared research that addresses high-risk, high-impact needs with a broad application throughout the IOFs. In FY 2003, the Combustion portfolio included three active projects (see Exhibit 6). In addition, there are a number of combustion-related projects in other components of the ITP (Exhibit 7).

## Exhibit 6 Active Combustion Projects in FY 2003

**Ultra-Low NO<sub>x</sub> Burners with Flue Gas Recirculation and Partial Reformer** – The goal of this project is to develop low excess-air, ultra-low NO<sub>x</sub>, natural gas-fired industrial burners that can emit less than 5 vppm NO<sub>x</sub>. Work is currently underway for the development of the first commercial low-swirl burner. Project partners include Lawrence Berkeley National Laboratory, Coen Co., CMC Engineering, John Zink Co., Gasunie Research, Maxon Corporation, and MIT Plasma Science and Fusion Center.

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## Exhibit 7 Other Projects Relevant to the Combustion Portfolio

### Aluminum

- Development of an Innovative Vertical Flotation Melter and Scrap Dryer
- An Energy Savings Model for the Heat Treatment of Castings
- Low-Dross Combustion System

### Biomass

- Black Liquor Gasification Kinetics
- Catalyst for the Destruction of Tars in Gasification
- Development of Materials for Gasification
- GTI Boise Gasification Project

### Chemicals

- Development of Enhanced Heat Exchangers for Process Heaters

### Forest Products

- Intermediate-Sized Entrained Particles
- Improved Recovery Boiler Performance Through Control of Combustion, Sulfur, and Alkali Chemistry
- Development of Corrosion Resistant Chromium-Rich Alloys for Gasifier and Kraft Recovery Boiler Applications
- CFD Modeling, Shape Optimization, and Feasibility Testing of Advanced Black Liquor Nozzle Designs for Improved Energy Efficiency
- Control of Emissions from Wood Waste Burners and Wood Dryers
- Development of Methane De-NO<sub>x</sub> Reburning Process for Waste-Wood, Sludge, and Biomass-Fired Stoker Boilers

### Glass

- Development and Validation of a Coupled Combustion Space/Glass Bath Furnace Simulation
- Monitoring and Control of Alkali Volatilization and Batch Carryover
- Glass Furnace Combustion and Melting User Research Facility

### Metal Casting

- Sensing and Control of Cupola Furnace

### Petroleum

- Rotary Burner Demonstration (Combustion)

### Sensors and Controls

- Diagnostics and Control of Natural Gas-Fired Furnaces via Flame Image Analysis (Glass)
- Tunable Diode Laser Sensor for Combustion Control (Steel)
- Fiber-Optic Sensor for Industrial Process Measurement and Control (Glass)
- Thermal Imaging Control of High-Temperature Furnaces (Steel)

### Steel

- Dilute Oxygen Combustion System (Combustion)
- Low-NO<sub>x</sub> Boiler Demonstration
- NO<sub>x</sub> Emission Reduction by Oscillating Combustion (Combustion)
- Hot Strip Mill Transfer Bar Rapidfire™ Edge Heat Project (NICE<sup>3</sup>)

### Sensors and Controls

- Diagnostics and Control of Natural Gas-Fired Furnaces via Flame Image Analysis (Glass)
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## **R&D Highlights**

### **Steel**

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### **Forest Products**

In commercial power plants, methane de-NO<sub>x</sub><sup>TM</sup> reburn retrofits have proven their adaptability to burn high-volume biomass, wood wastes, and sludge, resulting in boiler energy efficiency improvements and reduced wastes and air emissions.

# TOOLS, PUBLICATIONS, AND RESOURCES AVAILABLE

## Combustion Resources

### ***Combustion Industry Vision***

The *Combustion Industry Vision* was developed from an ITP-sponsored workshop in 1998. The workshop combined the expertise of manufacturers and users of burners, boilers, furnaces, and other process heating equipment. The vision provides a background on today's combustion systems, and specifies strategic targets, competitive challenges, and the industry's next steps. The vision is available for download at: [http://www.oit.doe.gov/combustion/pdfs/combustion\\_vision.pdf](http://www.oit.doe.gov/combustion/pdfs/combustion_vision.pdf).

### ***Industrial Combustion Technology Roadmap***

In 1999, combustion system users and manufacturers joined forces to develop the *Industrial Combustion Technology Roadmap*. The document identified R&D priorities for the development of advanced, highly efficient combustion systems that U.S. industry will require in the future. In 2001, ITP convened industry workshops to update the roadmap. The *Industrial Combustion Technology Roadmap* (2002) lists the R&D initiatives needed for the next 20 years. The roadmap is available for download at: [http://www.oit.doe.gov/combustion/vision\\_roadmap.shtml](http://www.oit.doe.gov/combustion/vision_roadmap.shtml).

### ***Guide to Low-Emission Boiler and Combustion Equipment Selection***

In 2001, DOE's Industrial Technologies Program (ITP) sponsored efforts at the Oak Ridge National Laboratory (ORNL) for development of the *Guide to Low-Emission and Combustion Equipment Selection* for choosing low-emission boilers and combustion equipment. The guide addresses fundamental concerns that arise when planning a new steam or hot water boiler system to be operated in compliance with regulatory emission standards. The document became available in April 2002. The guide was developed in cooperation with the American Boiler Manufacturers Association (ABMA) and the Council of Industrial Boiler Owners (CIBO). This guide is available for download at: [http://www.oit.doe.gov/bestpractices/steam/pdfs/guide\\_low\\_emission.pdf](http://www.oit.doe.gov/bestpractices/steam/pdfs/guide_low_emission.pdf).

### ***Improving Industrial Burner Design with Computational Fluid Dynamics Tools: Progress, Needs, and R&D Priorities***

In September 2001, burner designers, end users, combustion researchers, and computer code developers participated in a workshop to explore the role of computational fluid dynamics (CFD) tools in the design of industrial burners. CFD tools have the potential to significantly improve burner design. The results from the workshop, summarized in this report, show the contributions of CFD to burner design today, and identify the R&D priorities. The document also describes the current progress of CFD, the benefits of CFD modeling, and future issues. This document is available at: [http://www.oit.doe.gov/combustion/pdfs/cfd\\_wkshp\\_report.pdf](http://www.oit.doe.gov/combustion/pdfs/cfd_wkshp_report.pdf).

### **Combustion R&D Brochure**

This brochure highlights the benefits of government and industry partnership collaborations in combustion R&D. The brochure is available at: [http://www.oit.doe.gov/combustion/pdfs/combustion\\_brch.pdf](http://www.oit.doe.gov/combustion/pdfs/combustion_brch.pdf).

## Process Heating Resources

### **Process Heating Tip Sheets**

The tip sheets provide useful information on basic methods to improve burner efficiency. The tip sheets are available at: [http://www.oit.doe.gov/bestpractices/process\\_heat/pdfs/et\\_check\\_burner.pdf](http://www.oit.doe.gov/bestpractices/process_heat/pdfs/et_check_burner.pdf).

### **Process Heating Supplement to Energy Matters**

This document provides information on system optimization, as well as current issues of the process-heating sector, and project specifics. The document is available at: <http://www.oit.doe.gov/bestpractices/energymatters/pdfs/procheat.pdf>.

### ***Roadmap for Process Heating***

The roadmap, sponsored by the Industrial Heating Equipment Association (IHEA) and DOE, became available on March 16, 2001. The document specifies the priority R&D goals and non-research goals for process heating improvement. The roadmap is available at: [http://www.oit.doe.gov/bestpractices/pdfs/process\\_heating\\_0401.pdf](http://www.oit.doe.gov/bestpractices/pdfs/process_heating_0401.pdf).

## **Steam System Resources**

### **Steam Tip Sheets**

A series of tip sheets provide information on useful methods to improve boiler efficiency and steam system best practices. The tip sheets are available at: [http://www.oit.doe.gov/bestpractices/technical\\_publications.shtml#steam](http://www.oit.doe.gov/bestpractices/technical_publications.shtml#steam).

### ***Steam System Opportunity Assessment for the Pulp and Paper, Chemical Manufacturing, and Petroleum Refining Industries***

Resource Dynamics Corporation developed this report with the assistance of industry, national laboratory, and best practices specialists to analyze the opportunities available for these three large steam consumer industries. The report is available at: <http://www.nrel.gov/docs/fy03osti/32822CD.zip>.

### ***Improving Steam System Performance – A Sourcebook for Industry***

This report provides a general background on steam systems and identifies performance improvement opportunities for end users. DOE, Lawrence Berkeley National Laboratory, and Resource Dynamics Corporation participated in a mutual effort for the development of this document. The report is available at: <http://www.oit.doe.gov/bestpractices/steam/pdfs/steamsourcebook.pdf>.

### ***Steam Digest***

Available directly from DOE's BestPractices Web site, *Steam Digest* contains a collection of articles published on steam system management and resources. Two consecutive years of *Steam Digest* archives are available for download at: <http://www.oit.doe.gov/bestpractices/steam/tools.shtml>.

### ***Guide to Low-Emission Boiler and Combustion Equipment Selection***

Oak Ridge National Laboratory developed this document to provide users with a guide for selecting low-emission boilers and combustion equipment. The guide covers topics for industrial, commercial, and institutional boilers, and presents technical and regulatory issues. The guide is available for download at: [http://www.oit.doe.gov/bestpractices/steam/pdfs/guide\\_low\\_emission.pdf](http://www.oit.doe.gov/bestpractices/steam/pdfs/guide_low_emission.pdf).

### ***Steam System Survey Guide***

Developed by Oak Ridge National Laboratory, the survey guide was prepared for steam system operational personnel and energy managers to help them identify opportunities available for energy and productivity savings. The guide is available for download at: [http://www.oit.doe.gov/bestpractices/steam/pdfs/steam\\_survey\\_guide.pdf](http://www.oit.doe.gov/bestpractices/steam/pdfs/steam_survey_guide.pdf).

### ***Review of Orifice Plate Steam Traps***

Oak Ridge National Laboratory prepared this document to help end users decide when orifice plate steam traps should be used in new or existing steam systems. The report provides background information, advantages and disadvantages of using orifice plate steam traps, and final recommendations. The document is available for download at: <http://www.oit.doe.gov/bestpractices/steam/pdfs/orificetraps.pdf>.

### **Technical Briefs**

A series of technical reports discuss steam cost calculations, heat-transfer solutions, steam system process control schemes, and the use of heat pumps for steam system fuel savings. The reports are available for download at: <http://www.oit.doe.gov/bestpractices/steam/tools.shtml>.

## Combined Heat and Power Resources

There are a series of documents and resources related to combined heat and power. Some of these resources are described below. For a complete list of resources, please visit: [http://www.eere.energy.gov/der/chp/docs\\_resources.html](http://www.eere.energy.gov/der/chp/docs_resources.html)

### ***National CHP Roadmap***

The roadmap, sponsored by the United States Combined Heat and Power Association, the U.S. Environmental Protection Agency, and DOE, became available in March 2001. The document specifies the priority R&D goals and non-research goals for CHP. The roadmap is available at: <http://www.eere.energy.gov/der/chp/pdfs/chproadmap.pdf>.

### ***Combined Heat and Power Market Potential for New York State***

This report, created by the New York State Energy Research and Development Authority, analyzed the CHP market potential for the State of New York, and concluded very positive results. The report became available in October 2002. The document can be found at: <http://www.nyserda.org/CHPFinalReport2002WEB.pdf>.

### ***Integrated Energy Systems (IES) for Buildings: A Market Assessment***

This report, created by Resource Dynamics Corporation, became available in August 2002. The document describes the integration of CHP and thermally integrated technologies (TAT) into Integrated Energy Systems. The full document is available at: [http://www.eere.energy.gov/der/pdfs/ies\\_report.pdf](http://www.eere.energy.gov/der/pdfs/ies_report.pdf).

## Energy Analysis – Targeting Energy Efficiency

**GPRA Analysis** was completed for projects considered in the FY 2005 budget. The analysis estimates the future benefits of emerging technologies in the Combustion portfolio based on market penetration, efficiency gains, and emission reduction capabilities.

**Process Heating Assessment and Survey Tool (PHAST)** introduces the user to process heating methods and tools capable of improving the thermal efficiency of heating equipment. The tool and its fact sheet are available for download at: [http://www.oit.doe.gov/bestpractices/process\\_heat](http://www.oit.doe.gov/bestpractices/process_heat). Training on the tool is available through DOE and a number of its Allied Partners (see <http://www.oit.doe.gov/bestpractices/training> for information on upcoming training sessions).

In order to help users get the most from the tool, DOE and the Industrial Heating Equipment Association (IHEA) offer the Qualified Process Heating Specialist program. Participants who successfully complete a qualification workshop exam receive the “Qualified Specialist” designation. To learn more about the PHAST qualification, please visit: [http://www.oit.doe.gov/bestpractices/software/phast\\_cert.shtml](http://www.oit.doe.gov/bestpractices/software/phast_cert.shtml).

**Business Value of Steam Efficiency Tool** allows the user to justify the economic value of system improvements and calculate benefits. The tool is available for download at: <http://www.oit.doe.gov/bestpractices/steam/pdfs/justify.pdf>.

**Alternative Financing for Steam Efficiency** is a presentation that describes the different available financing arrangements offered by energy service companies. The presentation is available at: [http://www.oit.doe.gov/bestpractices/steam/docs/alt\\_financing.ppt](http://www.oit.doe.gov/bestpractices/steam/docs/alt_financing.ppt).

**Steam System Technical Tools** are provided by members of the Steam Challenge Steering Committee. A list of tools can be accessed from: <http://www.oit.doe.gov/bestpractices/steam/tools.shtml>.

**Steam System Assessment Tool** allows the user to estimate the potential savings from steam system improvements. In this tool, input data is transformed into energy, cost, and emissions savings estimates. The tool is available for download at: <http://www.oit.doe.gov/bestpractices/steam/ssat.html>.

**Steam System Scoping Tool** allows end users to evaluate their system operation against identified best practices and develop awareness of available opportunities to increase steam system efficiency. The tool is available in both Visual Basic and MS Excel formats, and can be downloaded from: <http://www.oit.doe.gov/bestpractices/steam/tools.shtml>.

**Combined Heat and Power Tool** is designed to evaluate the feasibility of using Combined Heat and Power (CHP) systems in industrial process heating systems. The heating systems include fuel-fired furnaces, boilers, ovens, heaters, and heat exchangers used by industry. The tool analyzes the technical and economic feasibility of using gas turbine exhaust gases to supply heat to fluids (air, water, heating oils, etc.), to boilers or to an industrial furnace or oven. The tool allows the user to determine the required amount of heat and the appropriate size of the turbine needed to meet that requirement, and it allows the user to calculate payback periods and perform “what-if” analyses for various utility costs. The tool is currently being tested as a Beta version and will be made available to the general public following incorporation of modifications suggested by the testers.

# HOW TO GET INVOLVED AND CONTACT INFORMATION

## Partnership Information

Public-private partnerships are the foundation of ITP's technology delivery strategy. ITP includes its partners in every phase of the technology development process to focus scarce resources where they can have the greatest impact on industrial energy efficiency. To learn more, please visit our Web site at [www.eere.energy.gov/industry](http://www.eere.energy.gov/industry).

- Collaborative, **cost-shared research and development** projects are a central part of ITP's strategy. Annual solicitations provide technology development opportunities in a variety of energy-intensive industries.
- **Industries of the Future Partnerships** increase energy efficiency in the most energy-intensive industries. In addition to cost-shared research and development projects, industry partners participate in the development of vision and roadmap documents that define long-term goals, technology challenges, and research priorities.
- **Allied Partnerships** provide an opportunity for ITP to reach a broad audience of potential customers by allying with corporations, trade associations, equipment manufacturers, utilities, and other stakeholders to distribute industrial energy efficiency products and services. By becoming an Allied Partner, an organization can increase its value to clients by helping them achieve plant efficiencies.
- **State energy organizations** work with ITP in applying technology to assist their local industries. ITP assists states in developing IOF partnerships to mobilize local industries and other stakeholders to improve energy efficiency through best practices, energy assessments, and collaborative research and development.
- **EERE's technical programs** (of which ITP is one of eleven) give manufacturers access to a diverse portfolio of energy efficiency and renewable energy technologies and bring advanced manufacturing technology to the renewable energy community. For more information, access the EERE home page at [www.eere.energy.gov](http://www.eere.energy.gov).
- The President's **Climate VISION** (Voluntary Innovative Sector Initiatives: Opportunities Now) effort also offers opportunities for manufacturers to pursue cost-effective actions that will reduce greenhouse gas emissions. See [www.climatevision.gov](http://www.climatevision.gov) for details.

## Access to Resources and Expertise

The Industrial Technologies Program provides manufacturers with a wide variety of industrial energy efficiency resources to help your company cut energy use right away. Visit our site at [www.eere.energy.gov/industry](http://www.eere.energy.gov/industry) or call the EERE Information Center at 877-337-3463 to access these resources and for more information.

- ITP offers **energy management best practices** to improve energy efficiency throughout plant operations. Improvements to industrial systems such as compressed air, motors, process heat, and steam can yield enormous savings with little or no capital investment.
- Our suite of powerful system optimization **software tools** can help plants identify and analyze energy-saving opportunities in a variety of systems.
- **Training sessions** are held several times per year at sites across the country for companies interested in implementing energy-saving projects in their facilities. DOE software tools are used as part of the training sessions.

- ITP's qualified **industrial energy specialists** will work with your plant personnel to identify savings opportunities and train staff in the use of ITP software tools.
- Our extensive library of **publications** gives companies the resources they need to achieve immediate energy savings.
- **Plant-wide energy assessments** are available to manufacturers of all sizes interested in cutting their energy use. Cost-shared solicitations are available each year for plant-wide energy assessments. In addition, no-cost, targeted assessments are provided to eligible facilities by teams of engineering faculty and students from 26 university-based Industrial Assessment Centers around the country.
- The **DOE Regional Offices** provide a nation-wide network of capabilities for implementing ITP's technology delivery strategy. Regional Offices are located in Atlanta, Boston, Chicago, Denver, Philadelphia, and Seattle. Visit [www.eere.energy.gov/rso.html](http://www.eere.energy.gov/rso.html) for more information.

## **Where to Go for More Information**

**Visit our Web site** - [www.oit.doe.gov/combustion](http://www.oit.doe.gov/combustion)

**Learn about all EERE programs** - [www.eren.doe.gov](http://www.eren.doe.gov)

**Ask an Expert** - The Industrial Technologies Program's Clearinghouse is a great way to access ITP's resources. Clearinghouse experts are available from 9 a.m. to 8 p.m. EST (6 a.m. to 5 p.m. PST).

Phone: 1-800-862-2086

Fax: 360-956-2214

E-mail: [clearinghouse@ee.doe.gov](mailto:clearinghouse@ee.doe.gov)

**For print copies of DOE, EERE, and ITP Publications, contact -**

Energy Efficiency and Renewable Energy Clearinghouse (EREC)

P.O. Box 3048

Merrifield, VA 22116

Fax: 703-893-0400

Phone: 1-800-363-3732

E-mail: [doe.erec@nciinc.com](mailto:doe.erec@nciinc.com)

**For questions regarding Combustion portfolio activities, please contact -**

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## A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and great energy independence for America. By investing in technology breakthroughs today, our nation can look forward to a more resilient economy and secure future.

Far-reaching technology changes will be essential to America's energy future. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a portfolio of energy technologies that will:

- Conserve energy in the residential, commercial, industrial, government, and transportation sectors
- Increase and diversify energy supply, with a focus on renewable domestic sources
- Upgrade our national energy infrastructure
- Facilitate the emergence of hydrogen technologies as a vital new "energy carrier"

### The Opportunities

#### *Biomass Program*

Using domestic, plant-derived resources to meet our fuel, power, and chemical needs

#### *Building Technologies Program*

Homes, schools, and businesses that use less energy, cost less to operate, and ultimately, generate as much power as they use

#### *Distributed Energy & Electric Reliability Program*

A more reliable energy infrastructure and reduced need for new power plants

#### *Federal Energy Management Program*

Leading by example, saving energy and taxpayer dollars in federal facilities

#### *FreedomCAR & Vehicle Technologies Program*

Less dependence on foreign oil, and eventual transition to an emissions-free, petroleum-free vehicle

#### *Geothermal Technologies Program*

Tapping the Earth's energy to meet our heat and power needs

#### *Hydrogen, Fuel Cells & Infrastructure Technologies Program*

Paving the way toward a hydrogen economy and net-zero carbon energy future

#### *Industrial Technologies Program*

Boosting the productivity and competitiveness of U.S. industry through improvements in energy and environmental performance

#### *Solar Energy Technology Program*

Utilizing the sun's natural energy to generate electricity and provide water and space heating

#### *Weatherization & Intergovernmental Program*

Accelerating the use of today's best energy-efficient and renewable technologies in homes, communities, and business

#### *Wind & Hydropower Technologies Program*

Harnessing America's abundant natural resources for clean power generation

To learn more, visit [www.eere.energy.gov](http://www.eere.energy.gov)

### Industrial Combustion Systems

#### ***Industrial Technologies Program - Boosting the productivity and competitiveness of U.S. industry***



**U.S. Department of Energy**  
**Energy Efficiency**  
**and Renewable Energy**

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